HUMAN FACTORS RESULTS OF THE SURFACE MANAGEMENT SYSTEM RAMP TOWER DEMONSTRATION

Deborah H. Walton[*], Amy Spencer[†], Cheryl Quinn[*]
[*]NASA Ames Research Center, Moffett Field, CA 94035
[†]Ohio State University

Abstract

The Surface Management System (SMS), being developed at NASA Ames Research Center in conjunction with the FAA, is a decision support tool that helps air traffic controllers and air carriers manage aircraft movements on the surfaces of busy airports. By presenting information and advisories to the Tower, Terminal Radar Approach Control (TRACON), Center, and air carriers, SMS creates shared departure situational awareness among a variety of Air Traffic Control (ATC) and airline users, thereby increasing the efficiency, capacity, and flexibility on the airport surface. This paper discusses the SMS ramp tower demonstration that was conducted in August and October, 2002 at the FedEx ramp tower in Memphis, TN. Active FedEx ramp tower controllers and administrators participated in the demonstration, which consisted of four days and four nights of SMS use in the ramp tower. One purpose of the demonstration was to conduct human factors studies in order to receive feedback from a group of intended SMS users about the status of the current system, primarily focusing on the algorithm performance and the information provided to each user. To this end, controller observations were conducted, and usability, suitability, and acceptability questionnaires were administered. This paper summarizes the demonstration that was conducted in the FedEx ramp tower, the information presented to each ramp tower user, and the results of these human factors studies. SMS was found to be most useful to the controllers during the arrival operations and to the administrator during the departure operations. SMS-provided information enabled the ramp tower controllers to monitor the inbound traffic to their own spots and plan more efficiently for future demand. Information provided by SMS also enabled the administrator to monitor traffic flow and more effectively make traffic management decisions. The experience of conducting a demonstration in an operational ramp tower environment was valuable preparation for the future demonstrations in the ATC environment, which are scheduled to begin in 2003.

Introduction

Ramp tower controllers are airline employees responsible for all aircraft movements conducted in the airline ramp area. Specifically, ramp tower controllers are responsible for selecting aircraft for pushback, taxiing aircraft to the spots[1], handling arrival and departure conflicts, and handing aircraft off to the Air Traffic Control Tower (ATCT) Ground controller. In order to get information about the current state of the aircraft and airport resources, FedEx ramp tower controllers use several different information sources: air carrier provided tools, a commercially available filtered repeater of the Terminal Radar Approach Control (TRACON) radar, known as SkySource, radio frequencies for the Ground and Local ATCT controllers, and their out-the-window view. The FedEx ramp tower controllers also use a proprietary tool called the Ramp Management Advisory System (RMAS), which provides flight-specific information for each aircraft. This combination of tools provides a good picture of the current state of the airport. However, data regarding future departure demand on airport resources is not currently available.

NASA Ames Research Center, in cooperation with the Federal Aviation Administration (FAA), is developing a decision support tool for the surface environment known as the Surface Management System (SMS). The project is supported by NASA's Advanced Air Transportation Technologies (AATT) Project. SMS uses information provided by the new surface surveillance systems and departure plans provided by the air carriers in order to provide the Tower, TRACON, Center and air carriers with better information about current and future demand. SMS has a goal of creating shared awareness of the departure situation and improving the capacity, efficiency, and flexibility of the airport.

The features of SMS can be divided into two separate domains: the information, displays, and advisories used by the FAA users, and the data that is provided to the National Air Space (NAS) users. The purpose of the ramp tower demonstration was to study what information would be useful for SMS to provide to the NAS users. In order for NAS users to evaluate the SMS-provided data, displays were provided for the evaluation. These displays were suggestive of how SMS data might be used by NAS users, although development of operational user displays is not part of the SMS project scope. These field tests afforded the opportunity to more fully prepare for Air Traffic

[1] A "spot" is the location on an airport surface at which an aircraft is transferred from ramp control to FAA Tower control or vice versa.

Control (ATC) demonstrations that will begin in 2003.

SMS aids ramp tower controllers with a variety of tasks including managing congestion on departure, selecting the next aircraft for pushback, handling gate and alleyway conflicts, and maintaining runway utilization and airport situational awareness. SMS currently employs four types of user interfaces: map displays, timelines, load graphs, and flight and status tables. Map displays of the airport surface provide a two-dimensional representation of the airport and include flight-specific information on data tags. Timelines provide flight-specific information and predictive time information. Load graphs provide aggregate demand data. Flight tables and status tables provide information about various airport resources.

Prior to the ramp tower demos, the SMS research team conducted two simulations in order to solicit ATC user feedback about the SMS concept, the preliminary user interfaces, and the algorithm performance in a simulated ATCT environment. These real-time controller-in-the-loop simulations of SMS were conducted in the Future Flight Central (FFC) ATCT simulation facility at NASA Ames Research Center in September, 2001 and January, 2002. FFC is a 360-degree, high fidelity control Tower simulator designed to provide the look and feel of a Level V airport Tower cab. Developed as a joint effort between NASA and the FAA, FFC uses twelve large rear-projection screens and computer-generated imagery to provide a 360-degree out-the-window view. Controllers use standard headsets to talk to the pseudo-pilots who control the individual aircraft movements.

The results of these simulations indicated that, for ATCT users, map displays were well-liked by the Local and Ground controllers and while timelines had potential uses, both timelines and load graphs might be better suited for a Traffic Management Coordinator (TMC) or administrator position. Walton & Atkins (2002) described the experimental design and results of the simulations in detail.

Demonstration Overview

Demonstration Objectives

The objectives of the ramp tower demonstration were to: 1.) familiarize ramp tower users with the SMS concept and tools, 2.) solicit feedback from intended users about information provided by SMS as well as the algorithm performance, and 3.) demonstrate usability of SMS in the ramp tower environment.

Memphis Field Site

The SMS ramp tower demonstration was conducted at the FedEx ramp tower at Memphis International Airport (MEM). MEM has been listed as the largest cargo airport in the world for the past seven years. The airport serves as the hub for FedEx, the world's largest cargo airline, and Northwest Airlines (NWA) and its alliance partners (KLM Royal Dutch Airlines, Northwest Airlink, Continental Airlines, and Continental Express).

As shown in Figure 1, MEM has two main terminal/ramp complexes: ① the FedEx Hub and associated ramp area, which is located primarily in the north portion of the airport, and ② the passenger terminals, which are located in between two of the main runways. Additionally, there are two General Aviation ramps located to the north of the passenger terminal and a maintenance and UPS cargo area located on the east side of the airport.

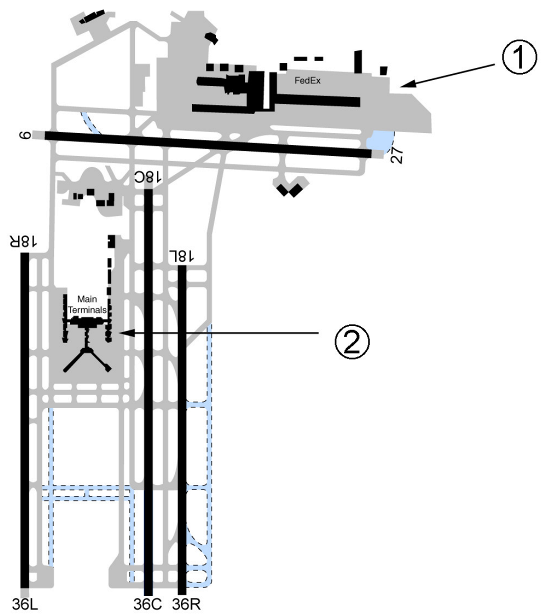

Figure 1: Layout of MEM airport

During the day, the peak hours of aircraft operations are associated with the hub operations of NWA. Runway use during this period is primarily on the parallel runways (18L-36R, 18C-36C, and 18R-36L), minimizing taxi time in and out of the Northwest terminal ramp area. In comparison, the nighttime peak operations consist primarily of FedEx traffic. The FedEx ramp is located at the north end of the airport and thus, during nighttime operations, the crosswind runway (27-9) is used in addition to the parallel runways in an effort to expeditiously handle surface traffic.

Participants

Normal staffing of the FedEx ramp tower in the daytime consists of one administrator and two ramp tower controllers, one for each of the west side and east side of the FedEx ramp. At night, the west and east sides are further broken down into Northwest and Northeast, Southwest and Southeast, and four controllers staff those positions.

The job of the FedEx ramp tower administrator is to supervise the strategic workings of the ramp. The tasks that are performed by the administrator involve managing the flow of aircraft off of the ramp and onto the active movement area controlled by the FAA ATCT controllers. The administrator accomplishes this by advising ramp tower controllers to hold aircraft at their gate or to increase or decrease the amount of traffic from each ramp area. In order to make these advisories, the administrator must maintain situational awareness of the airport configuration and runway utilization. For the purposes of the demonstration, displays were designed for the administrator that support the specific tasks of managing queue length at the runway and maintaining airport configuration and runway utilization situational awareness.

The FedEx ramp tower controllers are responsible for the tactical movements of aircraft on the ramp area including approving aircraft to attach a pushback tug, selecting aircraft for pushback, assigning a spot to an aircraft, and taxiing aircraft to their spot. For the purposes of the demonstration, displays were designed for the controller to support the specific tasks of selecting a flight to push back next and maintaining traffic flow situational awareness.

During the demonstration, human factors observers were stationed at the administrator position and one of the controller positions (the East position during the day and the Southwest position at night). In addition to the FedEx ramp tower staff members who participated as subjects, additional FAA controllers and TMCs and air carrier personnel participated in the demonstration as observers.

Schedule

The demonstration included two week-long sessions that were conducted during the weeks of August 26th and October 15th, 2002. Training was held two weeks prior to the initial demonstration and consisted of a 60-minute briefing followed by several hours of hands-on training using SMS. During the demonstration, both daytime and nighttime operations were observed. On the nights that training was conducted, human factors engineers observed overnight in the FedEx ramp tower to collect baseline data during nominal operations. The week of August 26th consisted of three nights of data collection with SMS running. The results of the August demonstration were subsequently used to make refinements to SMS before the second demonstration took place in October. The second demonstration consisted of four days and one night of data collection using the refined version of SMS.

Data Collection

Three different types of data were collected during the demonstration: SMS log files, human factors observations, and questionnaires. SMS log files collect data such as the aircraft target positions, user keyboard entries, runway assignments, and runways used by each aircraft.

The human factors data were qualitative observations made by the human factors observer stationed with the administrator or controller throughout the duration of the push[2]. These observations included information being used by the administrator or controller as well as the displays that were preferred and the questions that the users asked throughout the push.

Questionnaires were administered to controllers after each of the arrival and departure pushes. These questionnaires focused on the usability, suitability, and acceptability of the user interfaces (Harwood & Sanford, 1993). Usability refers to the ability of the controllers to readily obtain and use the information presented. Suitability refers to the appropriateness of the user interfaces to the task requirements and information needs. Acceptability reflects the controller’s trust in the information presented and his/her willingness to incorporate SMS into his/her task performance strategies. The questions consisted of ratings on a seven-point Likert scale, multiple choice, and open-ended questions. The questionnaires were designed to be specific to the arrival or departure push and were different for the administrator and the controller. All forms of data collection were confidential.

Display Types

SMS utilizes four types of displays to convey information and advisories: map displays, timelines, load graphs, and flight and status tables. A map display, in addition to providing the outlines of the taxiways, runways, and ramps, also shows the location and direction of travel for each aircraft.

[2] A departure push is a period of time during which airport traffic is composed primarily of one airline's departure traffic. An arrival rush is composed of arrival traffic. FedEx has two arrival rushes and two departure pushes each day.

Timelines, which are referenced to a physical location (e.g., a runway threshold or taxiway intersection), show the predicted times when aircraft will occupy that location but do not explicitly show the current location of each aircraft. Load graphs display the amount of present and forecasted demand on a specified airport resource (e.g., a runway, departure fix, or taxiway intersection). Load graphs display aggregate demand information rather than flight-specific information. Both timelines and load graphs have been used in the Center-TRACON Automation System (CTAS) Traffic Management Advisor (TMA) tool (Harwood & Sanford, 1993). Flight and Status tables provide flight-specific information in a tabular format. The SMS map displays, timelines, and load graphs are described in greater detail in Reference Walton.

Initial Demonstration Week

Controller displays

In order to facilitate determination of the information needs for the ramp tower users, initial display designs were presented from which the users could evaluate the accuracy and usefulness of the SMS-provided data. This paper does not present detailed information about the displays which were designed; instead, the paper focuses on the feedback which was received about the information content of the displays.

The information that was shown to the ramp tower controller was tailored to support the tasks they perform during arrival and departure operations. During the arrival rush, SMS supported the tasks of taxiing aircraft to their gates and maintaining situational awareness of surface operations. The information provided to support these tasks was: aircraft location, both on the airport surface and in the terminal area, provided on a map display; predicted arrival sequence, predicted ON[3] and IN times for each aircraft, predicted taxi delays to the controllers' spots and gates, and flight status, provided on two timelines and a flight table.

[3] A flight's ON time is defined to be the wheels-on time, and the IN time is the time at which the aircraft pulls into the gate. Similarly, OFF and OUT times are the wheels-up and pushback times for the aircraft.

The information that was provided to facilitate the controllers' departure tasks of selecting the next aircraft for pushback and maintaining situational awareness of surface operations was: aircraft location information (primarily in the ramp area), provided on a map display; predicted pushback time and predicted sequence of aircraft leaving the ramp area, provided on a timeline; and flight status, provided on a flight table.

The displays for the ramp tower controller were provided on one monitor. Initially, a full-size monitor was installed near the southwest ramp tower controller location, however, due to space limitations in the FedEx ramp tower, it was not possible for the controller to make full use of the SMS displays. Therefore, a laptop display was provided for the controller position. Despite being a smaller screen size than a full-size monitor, the flexibility of the location of the laptop allowed the controller to have full access to the SMS displays.

Controller feedback

Primarily, during the initial week of the demonstration, controllers' interactions with SMS consisted of comparing the information on SMS with information presented on RMAS. However, as their familiarity with SMS increased, the controllers began using SMS-predicted ON and IN times during the arrival rushes to update information in RMAS that they had missed, as well as to update information for flights that they could not see out the window due to their location on the airport. Additionally, controllers reported using the predicted arrival sequence from SMS to "keep ahead of radio calls" (i.e., to give them advance warning that a flight was arriving before hearing about it on the ATCT Ground or Local frequency). According to the controllers, the most useful information during the arrival rush is estimated times of arrival (ETAs) and landing sequence. This information was most likely listed as most useful because it is information that the controllers currently get from listening to the ATCT radio frequencies. In SMS the information is provided visually and is available for them to reference. The predicted arrival times in SMS were given an acceptability rating of mean = 3.3, $\sigma = 0.6$ on a scale of 0 to 4, where 0 = completely unacceptable, and 4 = completely acceptable, and the acceptability of the predicted aircraft sequence was rated as a mean = 2.7, $\sigma = 1.2$ on the same scale.

During the departure push, the controllers reported using the positional information provided by SMS to determine the departure queue lengths as well as using the flight-specific information from the flight table to confirm information provided to them by

RMAS. Controllers requested that the information provided to them be displayed such that they could compare active aircraft (i.e., aircraft that had already pushed back) against the airline' s schedule for the departure push. Additionally, some controllers asked for aircraft to be identified by their departure ramp area in order to determine the number of aircraft pushing from each ramp. This is interesting because it highlights a deviation from the controllers' stated tasks. While this information is generally used by an administrator to manage runway queue length, it appeared that most of the FedEx ramp tower staff rotate through the positions of controller and administrator, and so the differentiation between the two roles can be mixed for some of the staff members.

Administrator displays

The ramp tower administrator is located in the center of the tower, facing south towards the runways. Two full-size monitors were located at the administrator position. The map display was provided on one monitor, while the timelines, load graphs, and flight and status tables were provided on the second monitor.

The information that was provided to facilitate the administrator' s arrival task of maintaining situational awareness of surface operations was: aircraft positional information on the airport surface, provided on a map display; predicted arrival sequence and predicted ON times, provided on a timeline; undelayed arrival and departure demand, provided on a load graph; and flight status and runway status information provided on status tables.

The departure tasks for the administrator include managing congestion on departure and maintaining situational awareness of surface operations. The information provided was: aircraft location information on the airport surface provided on a map display; predicted OFF times and predicted queues (specific aircraft in the queue) at the runway, provided on a timeline; predicted and current queue length, undelayed arrival and departure demand, and predicted overall delay, provided on load graphs; and flight status, departure fix status, and runway status information, provided on status tables.

Administrator feedback

As with the controllers' responses, the feedback received from administrators during the initial demonstration week dealt primarily with the various display types as well as requests for information that was not available with the default display set-up.

The administrators reported that they were very interested in the predicted aircraft sequence and positional information provided by SMS. The administrators also asked for several pieces of information that were not already being specifically shown in the SMS displays that were presented during the initial demonstration. They requested that the information be color-coded to show flight status and predicted arrival runway. The administrators also expressed an interest in having taxi times displayed for each aircraft in order to help them minimize the taxi times for each aircraft. While taxi times are implicitly shown in the SMS timelines (the time between the pushback and the predicted departure time is the taxi time), it is not specifically called out for each aircraft. The administrator also requested information about active aircraft versus scheduled aircraft so that they could monitor how efficiently the rush was progressing in comparison with the airline' s planned schedule. According to the administrators, the most important pieces of information for the arrival rush are accurate ETAs and accurate aircraft landing sequence.

During the departure push, the administrators asked for the information on the timelines to be filtered to show only FedEx flights instead of all flights on the airport surface. Additionally, the administrators asked for aircraft location information for aircraft both on the airport surface as well as in the terminal area. According to the administrators, the most useful information for the departure push was current and predicted runway queue lengths because this information helped them manage the runway queue lengths, by helping them decide when to hold aircraft at the gate.

Inter-demo refinements

Based on the results of the first demonstration, the SMS displays and algorithms were refined before returning to MEM for the second week of the demonstration. Some of the display refinements included the addition of range rings to the map, the ability to rotate the map display to match the controllers' out-the-window view, an improvement in color-coding (making the colors more distinct), and the ability to display history on the timelines in order to allow them to check on prior ON or IN times. Algorithms were refined in order to provide improved prediction accuracy for OUT and IN events, improved runway prediction accuracy for arrivals, and a method to account for flights delayed by maintenance issues after pushback was implemented.

Second Demonstration Week

User Feedback

During the second week of the demonstration it became clear, both via observations and questionnaire results, that SMS data is most useful to the ramp tower controllers during the arrival rush and most useful to the administrator during the departure push.

During the arrival rush, the controllers used the predictions provided by SMS to monitor the inbound traffic for aircraft arriving to their own ramp areas. Additionally, they used positional information to determine the delay each aircraft would incur in its taxi to the ramp, thereby enabling them to plan more efficiently for periods of higher and lower demand. The pieces of information reported to be most useful to the controllers during the arrival rush were: predicted ON times, positional data once aircraft were on the airport surface, flight-specific destination (gate or spot), predicted inbound sequence, and flight status information.

During the departure push, the administrators used the information provided by SMS to supplement their out-the-window view and make decisions about holding aircraft in the ramp in order to minimize taxi times. The positional data provided by SMS assisted the administrator in determining when to hold traffic heading to runway 36L, which was not visible from the ramp tower, and the information comparing active aircraft against the airline' s schedule helped the administrator determine when to advise controllers to hold aircraft or slow the rate of pushbacks to particular runways. The administrators reported that the most important pieces of information during the departure push were: the amount of traffic heading to each runway that was currently pushing back or scheduled to push back, location information for aircraft already moving, queue length at the runways, and notification of late inbound aircraft.

One particular event highlighted the importance of late inbound notifications. During one afternoon departure push, the administrator noticed the SMS load graph displaying information about an anticipated arrival aircraft approximately 15 minutes away from the airport. After confirming this information on RMAS, the administrator immediately notified the controller who would be handling this aircraft. The controller had independently noticed this late aircraft on his SMS timelines. The aircraft was scheduled to arrive via Spot 6, which was going to be blocked at the predicted time by a departing aircraft which had already been cleared for pushback. In response to this new information, the controller was able to send the departing aircraft out of a different spot and avoid a conflict on the ramp.

Summary and Future Work

A major goal of the SMS Ramp Tower demonstration was to determine ramp tower controllers' and administrators' opinions about the current state of SMS-provided data. To this end, human factors studies investigated users' preferences via questionnaires and observations. Data were acquired about the specific information that can be provided by SMS to support each user in a ramp tower environment. The roles of each airline controller in the context of SMS were better defined, and the potential uses of SMS were explored.

According to questionnaire results and observation data, it was determined that in the ramp tower, SMS is most useful to the controllers during the arrival operations and to the administrator during the departure operations. SMS-provided information enabled the ramp tower controllers to monitor the inbound traffic to their own spots and enabled them to plan more efficiently for future demand. Information provided by SMS also enabled the administrator to monitor traffic flow on all portions of the airport more easily and make decisions to control traffic flow and manage taxi times.

The experience of conducting a demonstration in an operational ramp tower environment was valuable preparation for the future demonstrations in the ATC environment. The human factors results from this ramp tower demonstration will be used to further refine SMS and to define information requirements for airline users of SMS. ATC Tower shadow-mode demonstrations are scheduled to begin in 2003. Feedback from ATCT user groups will contribute to further SMS development and refinement.

References

Harwood, K. & Sanford, B. (1993) *Denver TMA Assessment*. (NASA Contractor Report 4554). Moffett Field, CA: CTA Incorporated.

Walton, D. & Atkins, S. (2002) *A Simulation Evaluation of the Surface Management System User Interfaces*. (Planned to be published as a NASA TM). Moffett Field, CA: NASA.